

AUDIO NOISE REDUCTION CIRCUITS

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Audio Noise

Simple circuit employing germanium diodes as nonlinear elements reduces phonograph record-noise without substantially affecting desired signal. Single-channel unit up to 6,000 cycles and a three-channel 0-to-12 kilocycle version for broadcast stations are described

NOISE is one of the most disagreeable forms of distortion that occurs in sound reproducing systems. Therefore, any means which reduces or mitigates noise is extremely useful and important.

There are many ways of increasing the signal-to-noise ratio thereby reducing the deleterious effects of noise. A few of the systems that have been used may be listed; (1)

a system in which the high-frequency response is attenuated; (2) a system with suitable pre-compensation and post-compensation so that the high-frequency response is accentuated in recording or transmitting and attenuated in reproducing or receiving; (3) a system using two channels—one channel is used to carry the signal and the other channel to control the amplitude of the signal in reproduction; (4) a system in which the high-frequency cutoff of the reproducing system is automatically made a function of the general level of the signal.

The use of two channels, in which one is used as a volume control, has been applied in some special cases but, in general, is impractical because two channels are not available in conventional reproducing systems.

Systems in which the high-frequency response is accentuated in recording or transmitting and attenuated in reproducing or receiving are used in phonograph and sound motion-picture reproduction as well as frequency-modulation radio broadcasting. This procedure is quite effective, but in some systems it is also necessary to reduce the frequency transmission band in order to obtain a substantial reduction in noise.

A system in which the high-frequency range is limited introduces frequency discrimination against high-frequency sounds, regardless of whether the high-frequency cutoff is fixed or is automatically controlled by the signal. Of course, in

the case of the automatic system frequency discrimination occurs only when the amplitude of the signal is small. Nevertheless, this discrimination may be serious for certain sounds.

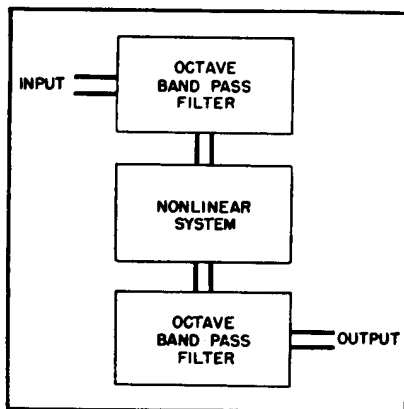


FIG. 1—Noise reduction system elements

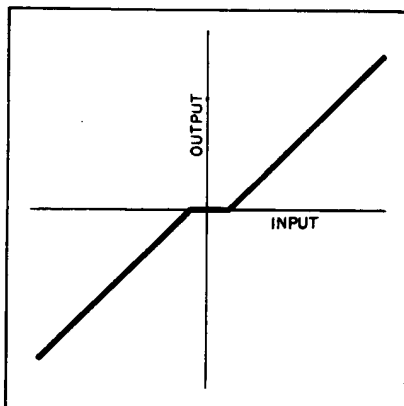


FIG. 2—Amplitude characteristics of a simple nonlinear element

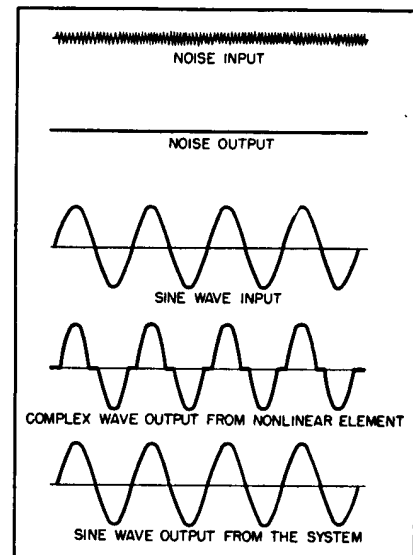


FIG. 3—Response of noise reduction system to noise and sine wave input

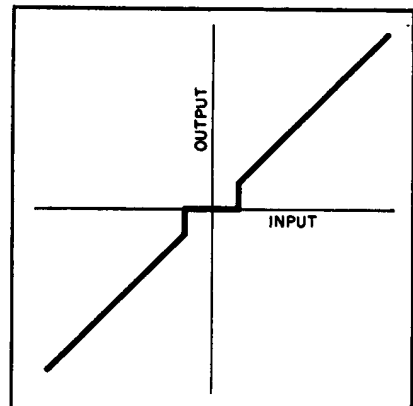


FIG. 4—Amplitude characteristics of a complex nonlinear element

Reduction Circuits

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The noise reduction system to be discussed here employs a nonlinear element. The nonlinear element allows the useful signal to pass and discriminates against noise. This system lowers the ground noise level and thereby increases the signal-to-noise ratio without discrimination against the useful part of the signal.

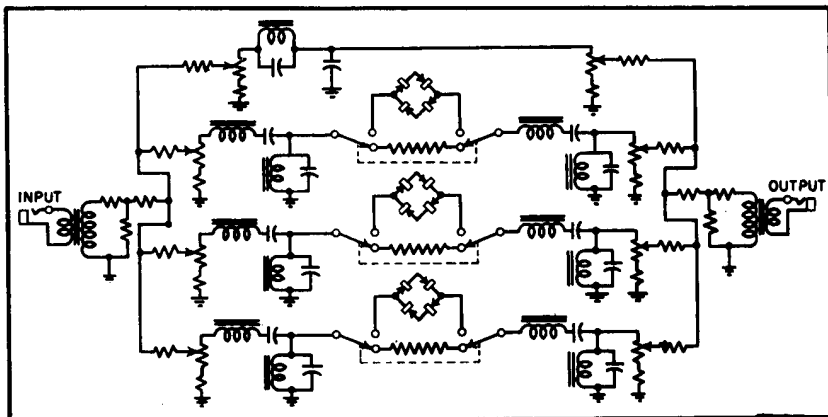
Principle of System

A block diagram of the system is shown in Fig. 1. Band-pass filters which pass frequencies over a range of an octave are used at the input and output of the nonlinear element. The amplitude characteristic of the nonlinear element is illustrated in Fig. 2. As will be described later, this amplitude characteristic can be obtained with a properly biased diode vacuum tube or crystal rectifier. By using this method the system will exhibit high attenuation to signals of small amplitudes.

The response of the noise reduction system to noise and a sine wave is depicted in Fig. 3. If the amplitude of the noise is kept below the response range of the noise reduction system, the noise will not be reproduced. The response of the noise reducing system to a sine wave signal is also shown. The output of the nonlinear element contains the fundamental, harmonics, and subharmonics of the fundamental. However, since the pass band of the input and output band-pass filters is an octave, the harmonics and subharmonics will not be transmitted by the system. The



Panel and chassis views of experimental three-channel noise suppressor in use by American Broadcasting Co., described by John Colvin at NAB convention in Atlantic City, September 1947



Schematic wiring diagram of ABC three-channel noise suppressor. Any of the channels can be switched to suppression or straight-through operation and the two top bands can be switched off entirely

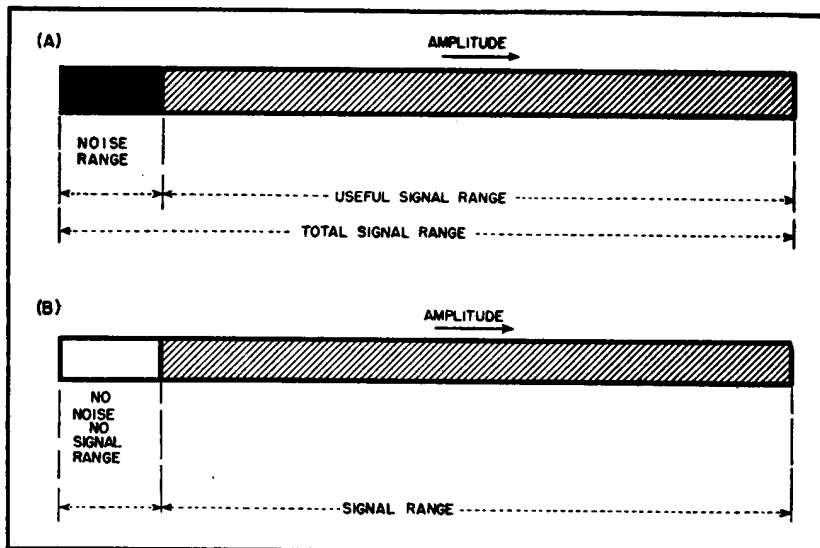


FIG. 5—(A) Amplitude ranges of total signal, noise, and useful signal in a conventional reproducing system; (B) amplitude ranges in a system with noise reduction

output wave, then, is a sine wave of the same frequency as the input sine wave. If two sine waves of different frequencies are impressed upon the system, the two frequencies must lie within the pass band octave in order to be admitted by the input band-pass filter. The output of the nonlinear element contains harmonics and subharmonics of the two fundamental frequencies, but these are rejected by the output band-pass filter. The output of the nonlinear element also contains the sum of the two frequencies and the difference of the two frequencies. Since the input is confined to an octave, the band-pass output filter will reject the sum and difference frequencies.

To summarize; if the input and output band-pass filters are confined to one octave or less, there will be no distortion produced by the system in the form of spurious harmonics, overtones, subtones and sum or difference tones. There will be some amplitude discrimination against signals of small amplitude. This discrimination may be reduced to a negligible quantity by employing the amplitude characteristic of Fig. 4. In this case, the transition from no response to a constant input-output relationship occurs very suddenly.

The gain in signal-to-noise by the use of a noise discriminating system employing a nonlinear element

is depicted in Fig. 5. The amplitude ranges of the signal, the noise and the useful part of the signal are shown in Fig. 5A. The portion of the signal amplitude which is equal or less than the amplitude of the noise may be considered to be lost and of no value. By means of the nonlinear element, it is possible to eliminate the reproduction of all amplitudes below a certain level. If this amplitude corresponds to the maximum amplitude of the noise, the noise will not be reproduced. This condition is depicted in Fig. 5B. It will be seen that the noise reducing system reduces or eliminates the noise but does not increase the dynamic range of the signal. In effect, the nonlinear sys-

tem separates the signal and noise in amplitude.

Nonlinear Elements

One way of obtaining the amplitude characteristics of Figs. 2 and 4 is by the use of unilateral conducting devices. These may be vacuum tube, crystal, copper-oxide or selenium rectifiers. Use of the vacuum tube diode and the germanium crystal rectifier as the nonlinear element is described below.

The input versus output voltage characteristics of two opposed germanium crystal rectifiers with a resistance load is shown in Fig. 6. It will be seen that the ratio of the output to the input voltage decreases rapidly below an input of 0.1 volt. This is due to the contact potential in these rectifiers. Supplying a bias voltage of about 0.1 volt.

The input-to-output voltage characteristic of two opposed biased vacuum-tube diode rectifiers is shown in Fig. 7. Below the bias voltage, the impedance of the rectifier is practically infinite because the reverse current in a vacuum-tube rectifier at audio frequencies is negligible.

The nonlinear elements of Figs. 6 and 7 approximate the amplitude characteristics of Fig. 3. The characteristics of Fig. 4 can be approximated using two sets of opposed biased diodes, one in series with the line and the other in shunt with the line. By a suitable choice of diodes, resistances and bias voltages, the characteristics shown

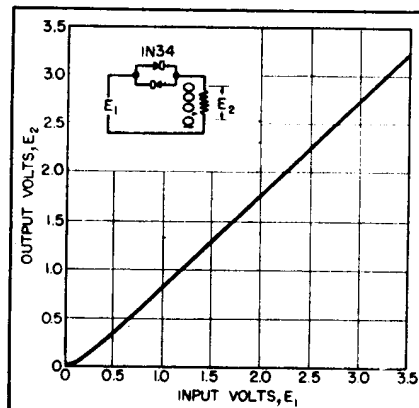


FIG. 6—Input-output voltage characteristics of two opposed germanium diodes

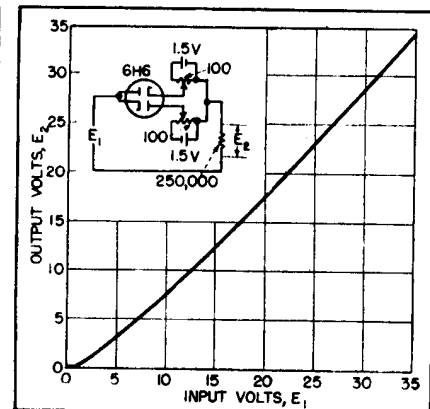


FIG. 7—Input-output voltage characteristics of two opposed biased tubes

below in Fig. 8 can be obtained.

Thermal noise energy per cycle is independent of the frequency. However, in a phonograph record, the noise per cycle increases with increase of frequency, as indicated in Fig. 9. A consideration of the noise spectrum of a conventional shellac phonograph record, together with typical living-room noise spectrum and the response-frequency characteristics of the ear, indicates that a relatively sharp cutoff is required at about 4,500 cycles in order to obtain tolerable reduction of the noise level in a conventional phonograph reproducing system. In view of the characteristics of phonograph reproduction, it was felt that the threshold type of noise reduction system would be particularly effective in reducing noise produced by records.

A block diagram of a phonograph reproducing system employing a simple audio antinoise system is shown in Fig. 10. The noise reduction takes place in the octave between 3,000 cycles and 6,000 cycles. This allows reproduction to 6,000 cycles with the low noise characteristics of a 3,000-cycle cutoff. The circuit diagram including the pre-amplifier, the filters and the nonlinear elements is shown in Fig. 11. The system consists of two crystal rectifiers, one vacuum tube, four inductors, eight capacitors, two potentiometers and five resistors. The response-frequency characteristics of the low-pass channel, the band-pass channel and the com-

bination are shown in Fig. 12. Referring to the block diagram of Fig. 10, it will be noted that the input and output potentiometers are complementary and ganged together so that the overall gain is not changed by varying the potentiometer setting. In this way, the

low response range of the nonlinear system can be adjusted to correspond to quiet, medium and noisy records by varying the ganged potentiometers. Noise reduction in the unit described is about 15 db for shellac home-type records.

The threshold noise reduction

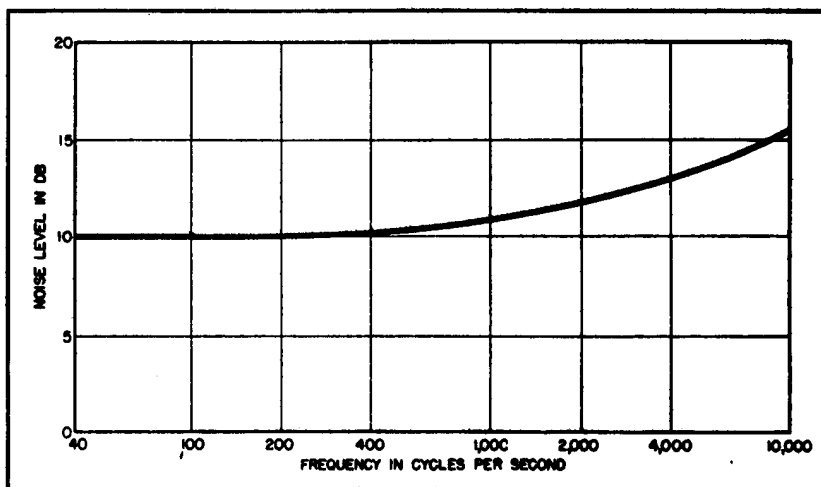


FIG. 9—Noise per cycle response-frequency characteristic of a phonograph record

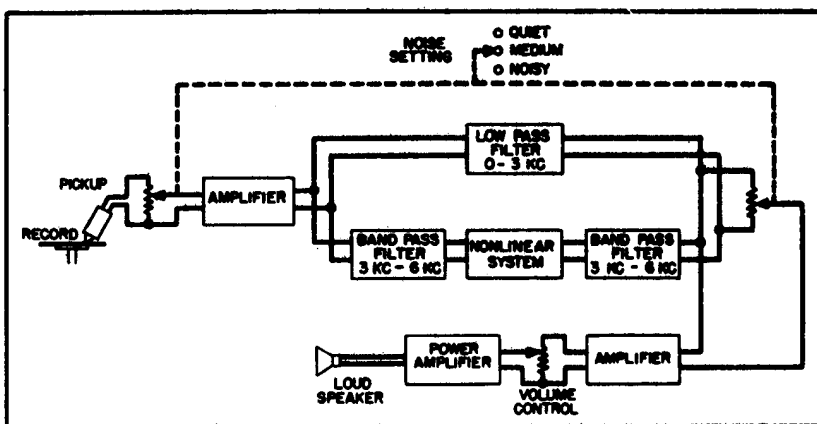


FIG. 10—Phonograph reproducer with simple audio noise reduction

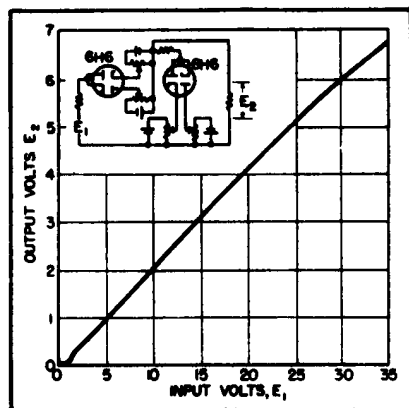


FIG. 8—Characteristics of two sets of opposed biased diodes specifically connected

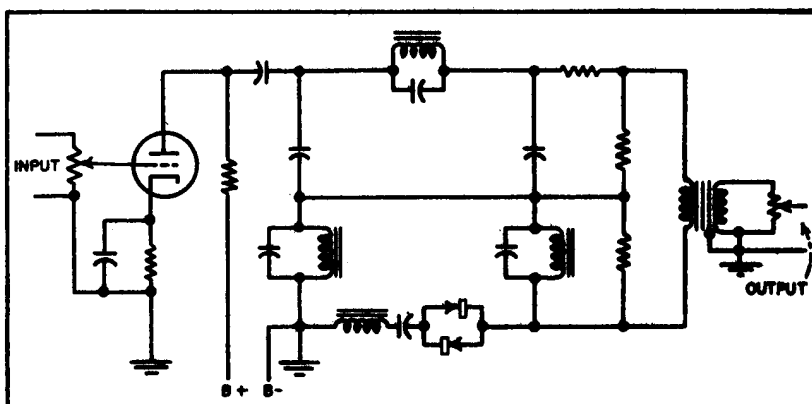


FIG. 11—Circuit diagram of block system in Fig. 10, showing amplifier, 0-3 kc low pass filter, band-pass filters, and nonlinear system

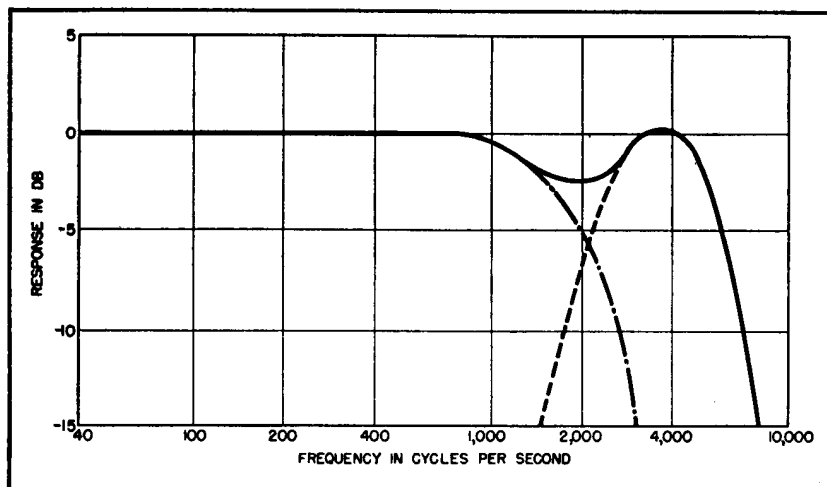


FIG. 12—Voltage response frequency characteristic of low-pass, band-pass (broken lines) and combined channels for the circuit of Fig. 11

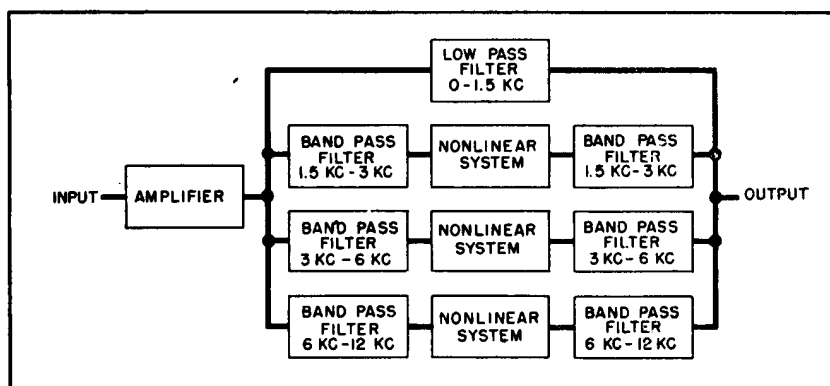


FIG. 13—Wide-range noise reduction system for 0-to-12 kc use

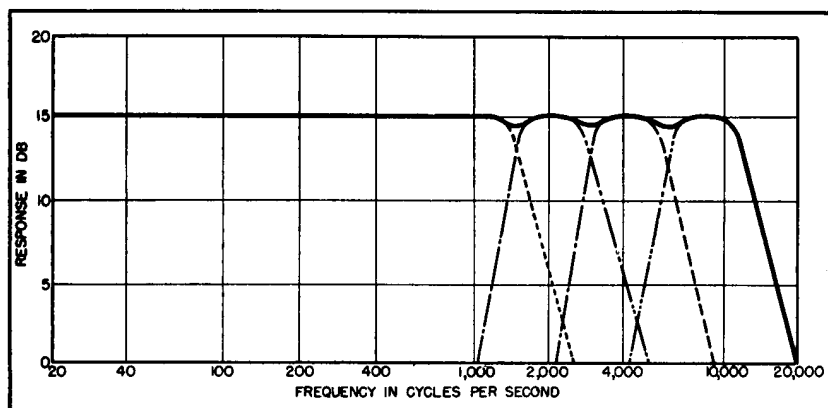


FIG. 14—Overall characteristics of three-channel system in Fig. 13. Band-pass channels are indicated by broken lines

system described possesses advantages as contrasted to any system in which the high-frequency cutoff is a function of the general level of the sound. In such systems rectifiers are employed to supply the control bias of the tubes in the filter system. The retreat time of these rectifiers is relatively large,

which means that with high-level sounds of short duration the high frequency cutoff may not follow the sound. If the cutoff remains at a high frequency after the level of the sound has returned to a low level, the result is an audible swishing of the noise. With sounds having a low general level, the high-

frequency cutoff will be relatively low regardless of the overtone structure, with a resulting loss of overtones. In the system here described the output of the nonlinear element in the transmitting region corresponds to the input because the operation of the nonlinear element is instantaneous as far as audio frequencies are concerned. Therefore, there will be no swishing on high amplitude sounds of short duration. Furthermore, it transmits any sound which lies above the noise level. Therefore, there is no discrimination against any frequency band in this domain regardless of the general level of the sound.

Multiple Channel System

The system described, with an upper cutoff frequency of 6,000 cycles, has a much wider frequency range than the conventional home phonograph reproducing system, and the noise level is also lower. Extending the range beyond this frequency requires increased power output and improved loudspeaker systems. However, for wider range transcription phonographs an even wider frequency range is desirable.

A system with an upper cutoff of 12,000 cycles and three channels of noise reduction is outlined in the block diagram of Fig. 13. This system uses the nonlinear elements of Fig. 8. Each nonlinear system is equipped with a separate bias control so that the noise can be reduced in each band without discrimination against the useful signal. The response-frequency characteristic of the separate channels and the overall response is shown in Fig. 14. Conventional band-pass filters are used to confine the response to octave bands. A two-stage input amplifier overcomes the loss in the filters and nonlinear elements. Noise reduction of up to 20 db can be obtained in each of the channels.

The audio noise reduction system described is particularly effective in phonograph reproduction because the noise per cycle increases with the frequency. However, it may be applied with good results in other sound reproducing systems, as for example, sound on film, magnetic wire or tape, and radio broadcasting.